EVALUATION OF OCEAN COLOR SCANNER (OCS) PHOTOGRAPHIC AND DIGITAL DATA:

SANTA BARBARA CHANNEL TEST SITE, OCTOBER 29, 1975 OVERFLIGHT

by

Steven P. Kraus, John E. Estes,
Michael R. Kronenberg, and Earl J. Hajic

October 18, 1977

(NASA-CR-155171) EVALUATION OF OCEAN COLOR SCANNER (OCS) PHOTOGRAPHIC AND DIGITAL DATA: SANTA BARBARA CHANNEL TEST SITE, 29 OCTOBER 1975 OVERFLIGHT (California Univ.) 54 p HC A04/MF A01 CSCL 20F

N77-33587

Unclas G3/43 50248

Principal Investigator: Dr. John E. Estes, Associate Professor
Department of Geography
Geography Remote Sensing Unit (GRSU)
University of California
Santa Barbara, California 93106

Prepared under Grant: National Aeronautics and Space Administration
NASA Grant No. NSG-5106

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This report presents a summary evaluation of Ocean Color Scanner (OCS) data acquired by a National Aeronautics and Space Administration (NASA) U-2 high altitude research aircraft over the Santa Barbara Channel, California designated test site on October 29, 1975 (NASA Ames Research Center Flight No. 75-186; OCS Flight No. 27). Ocean Color Scanner is a ten-channel, multispectral scanner developed by Goddard Space Flight Center (GSFC) as a test and evaluation system for an imaging radiometer scheduled to fly on Nimbus G in 1978. Primary responsibilities of Geography Remote Sensing Unit (GRSU) personnel in the OCS test program were to evaluate the detection and discrimination capabilities of the system for marine resources, oil pollution and man-made sea surface targets of opportunity in the Santa Barbara Channel. Assessment of the utility of OCS for the determination of sediment transport patterns along the coastal zone was a secondary goal.

Data products provided by GSFC for the October 29, 1975 overflight were in digital and analog formats. In evaluating the OCS data, automated and manual procedures were employed. A total of four channels of data in digital format were analyzed, as well as three channels of color combined imagery, and four channels of black-and-white imagery. In addition, 1:120,000 scale color infrared (CIR) imagery acquired simultaneously by NASA with the OCS data were provided to GRSU for comparative analysis purposes.[1]

---

[1] Normally GRSU would provide low-altitude sea truth/field verification photographic support coincident with OCS overflights. However, this was not possible for the October 29, 1975 flight which occurred approximately four months prior to the March 1, 1976 start date for our NASA Grant NSG-5106.

This progress report is divided into five sections. Section 1.0 contains background information on the Ocean Color Scanner, a description of the Santa Barbara Channel test site, and a summary listing of data products provided for evaluation. Section 2.0 describes the analysis procedures employed in evaluating the October 29, 1975 OCS data. Section 3.0 provides descriptive data on targets of interest in the Santa Barbara Channel. Section 4.0 details the results of our analysis of the detection and discrimination characteristics of the OCS data for the various classes of targets. Section 5.0 provides summary conclusions and suggestions for future research.

1.0 SYSTEMS DESCRIPTION, TEST SITE LOCATION, AND DATA SETS

1.1 Ocean Color Scanner (OCS)

The National Aeronautics and Space Administration (NASA) Ocean Color Scanner (OCS) is a ten-channel multispectral scanner developed by NASA Goddard Space Flight Center (GFSC) as a breadboard system for an imaging radiometer scheduled to fly on Nimbus G in 1978. The scanner has a 90^{o} total scan angle and a spatial resolution of 3.5 milliradians. The peak wavelengths and full bandwidths at half maximum for each of the ten channels are shown below:

Channel	Wavelength (nm)	Full Width (nm)
1	427	22.5
2	465	21.5
3	500	27.5
4	544	24.5
5	582	25.0
6	622	26.0
7	662	22.0
8	701	20.5
9	735	22.5
10	774	23.0

OCS data output is recorded on one-inch, 14-track magnetic tape in analog form. In addition, any four of the channels can be recorded simultaneously in digital format.

Primary goals of the NASA OCS test program are to: 1) obtain simulated space imagery prior to the launch of Nimbus G, 2) apply and evaluate the data processing techniques planned for the satellite, and, 3) determine the impact of atmospheric scattering on ocean color imagery. During the flight evaluation period, the scanner has been mounted and flown onboard a NASA U-2 high altitude aircraft.

1.2 Test Site (Santa Barbara Channel, California)

Imagery analyzed in this report were acquired over the Santa Barbara Channel, an OCS designated test site off southern California (Figure 1). The channel has prolific oil and gas seeps located offshore between Carpinteria and Point Conception and heavy concentrations of giant kelp (*Macrocystis pyrifera*) in beds extending along the coast from Ventura to Point Conception and surrounding the offshore islands. Ocean Color Scanner Flight 27 (NASA Flight # 75-186, 29 October 1975) covered portions of the Santa Barbara Channel from Ventura on the east to El Capitan on the west, north along the crest of the Santa Ynez Mountains and south to the Channel Islands. Two separate data runs were flown (Figure 2). Four major seep regions and thirteen individual kelp beds were located within the imaged areas, as well as a variety of man-made surface targets including piers and oil production platforms. The largest of the seep regions, situated between Goleta and Capitan released an estimated 50-75 barrels of crude oil per day (Allen and Schlueter, 1969) from three general areas of seep activity (Wilkinson, 1972). The remaining seep regions have been estimated to produce less than 50 barrels/per day. Normally wind and current conditions combine to merge individual seeps within

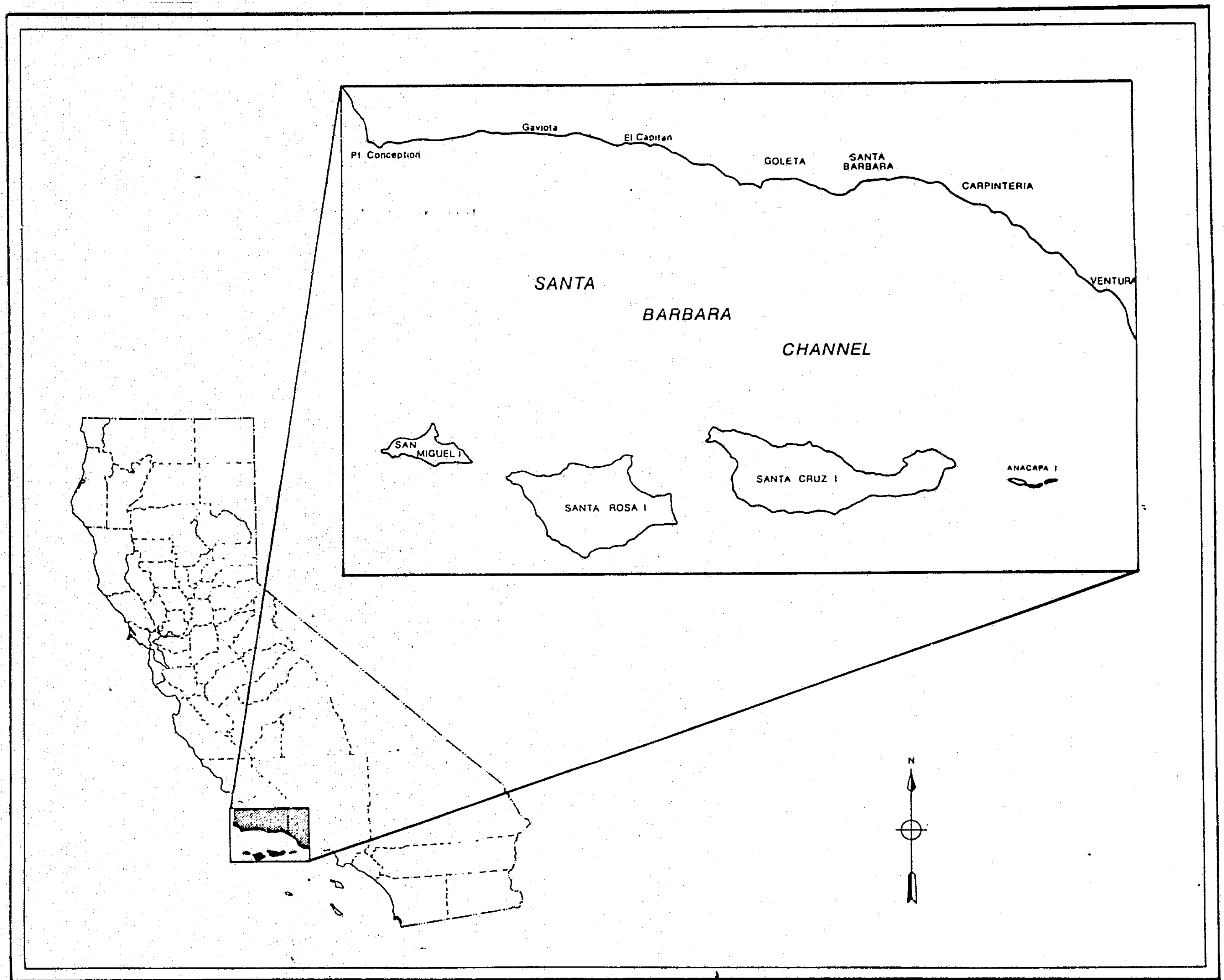


Figure 1. Location of the Santa Barbara Channel OCS test area.

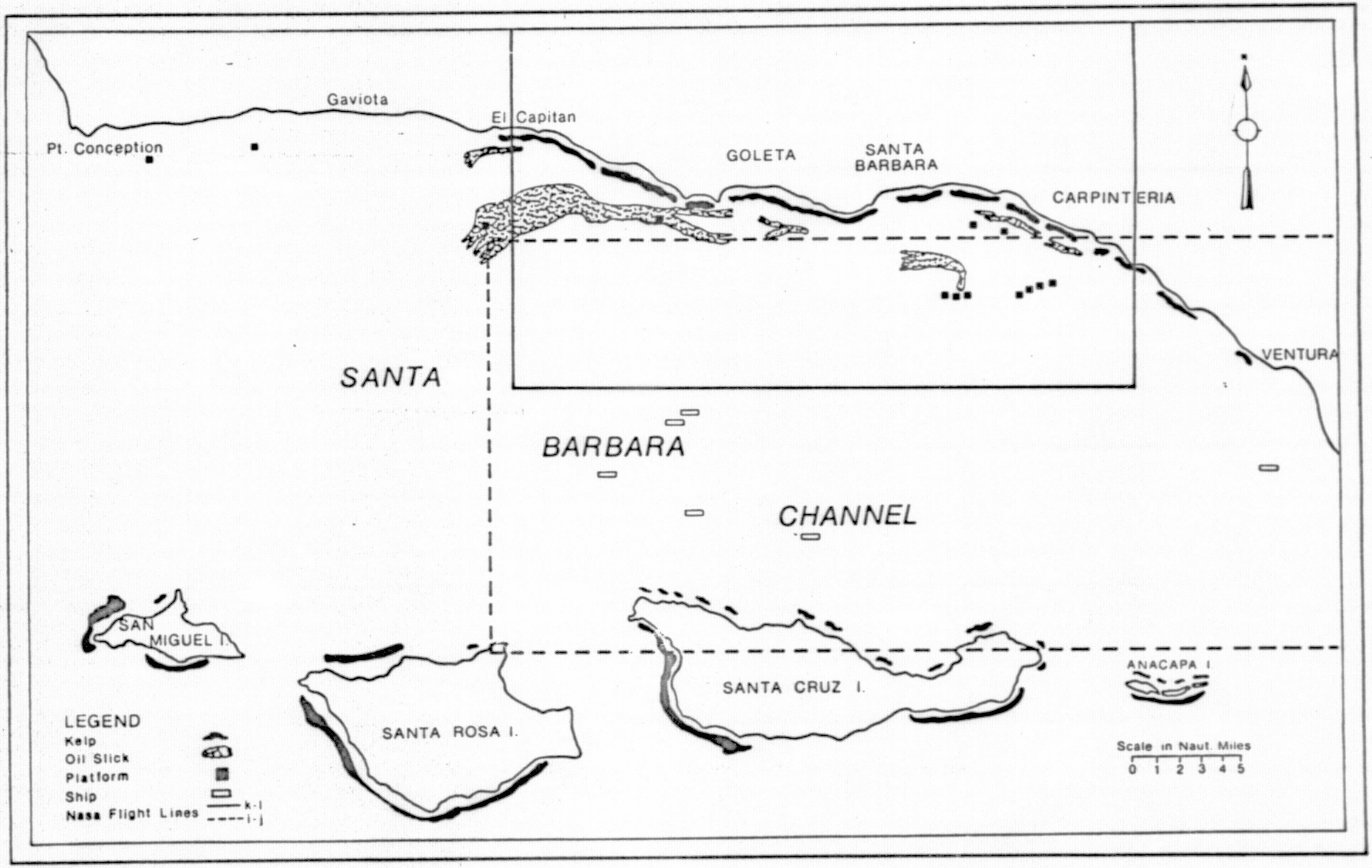


Figure 2. Target Location Map - Santa Barbara Channel, California, October 29, 1975.

major regions and surface slicks covering several square miles of ocean surface are common. Kelp beds at the time of the overflight ranged in size from .05 to .25 square miles. In addition to providing a habitat for fish sought after by both commercial and sport fishermen, harvesting of these beds provide the raw material for an important California industry.

1.3 Summary Listing of Data Sets Provided GRSU for Analysis (OCS Flight No. 27; October 29, 1975)

The Santa Barbara Channel test site is shown in Figure 2. It should be noted that coincident coverage of the test site on October 29, 1975 was limited to an area extending offshore between Carpinteria on the east and Capitan on the west, and a second area from Ventura on the east to the northeastern tip of Santa Rosa Island on the west.

Initial OCS image processing and data reduction were accomplished at GSFC, Greenbelt, Maryland. Following is a listing of computer tape and photographic data products provided by NASA for analysis:

- One (1) digital format magnetic tape containing Channels 2, 4, 5, and 7.
- Two (2) 8" x 10" negative photographic prints direct printed from transparencies produced from scanner analog magnetic tape channels 1 through 8 (individual frame size, per channel: 1-2/5" x 1").
- Two (2) 8" x 10" positive photographic prints direct printed from scanner analog magnetic tape. Channels 2, 4, 5, and 7 (individual frame size, per channel: 2-4/5" x 2").
- Two (2) 8" x 10" color combined photographic prints from scanner analog magnetic tape (Channels 2, 5, and 7).
- Seventeen (17) 8" x 10" color infrared (CIR) photographic prints (1:120,000 scale) comprising control frames 0054-0070 from the OCS overflight.

- Seventeen (17) 70 mm (2-1/2"x 2-1/10") color infrared (CIR) negatives (1:120,000 scale) comprising control frames 0054-0070.

Table 1 provides a detailed listing of individual data sets by flight line and GMT. Panatomic-X, Plus-X, and Aerial Color (SO-242) films also were acquired during the October 29, 1975 overflight. These were not provided by NASA/GSFC.

TABLE 1 Data Products for the Santa Barbara Channel Test Site Provided by NASA/GSFC

Type of Data Product	Flight Line*	Time (GMT)	Analyzed by GRSU Yes	Analyzed by GRSU No
Magnetic Tape, Digital Format (OCS Channels 2, 4, 5, and 7	i - j	19:42:42 - 19:50:08	X	
	k - l	19:52:42 - 19:57:12		X
Magnetic Tape, Analog, Negative Photographic Prints (Channels 1-8)	i - j	19:42:42 - 19:50:08	X	
	k - l	19:52:42 - 19:57:12	X	
Magnetic Tape, Analog Positive Photographic Prints (Channels 2, 4, 5, and 7)	i - j	19:42:42 - 19:50:08	X	
	k - l	19:52:42 - 19:57:12	X	
Magnetic Tape, Analog, Color Combined Photographic Prints (Channels 2, 5, and 7)	i - j	19:42:42 - 19:50:08	X	
	k - l	19:52:42 - 19:57:12	X	
Color Infrared (CIR), 1:120,000 scale negatives	i - j	19:42:42 - 19:50:08		X
	k - l	19:52:42 - 19:57:12		X

*NASA Ames Research Center Flight 75-186 Checkpoints (see Figure 2)

2.0 DATA ANALYSIS METHODS

Analysis of Ocean Color Scanner data was accomplished by GRSU investigators familiar with the locations of major targets of interest in the Santa Barbara Channel. Manual interpretation procedures were used to evaluate photographic imagery; digital tape data were automatically processed.

2.1 Manual Interpretation

Manual interpretation of photographic data from OCS Runs i-j and k-l over the Santa Barbara Channel (see Figure 2) was limited to an evaluation of black-and-white imagery and color combined prints. To determine target detectability and interpretability for various categories of targets, OCS photographic data sets were compared with concurrently flown conventional 1:120,000 scale color infrared (CIR) imagery. The following methodology was used by GRSU photo interpreters:

- Sea truth data (1:120,000 scale CIR imagery) and target location maps[2] for the Santa Barbara Channel were reviewed to determine the locations of all known natural and man-made targets in the imaged areas. Targets included surface slicks (oil and wind), kelp beds, oil platforms, piers, and large merchant vessels.
- Imaged marine and nearshore targets were annotated on frosted acetate overlays prepared for each data set.
- Where a correlation existed between a known target and an imaged target, the target was recorded as detected.
- Individual target returns were evaluated for interpretability and ranked on a scale from poor to good based on qualitative criteria.

---

[2] These included U.S. Geological Survey 7½ minute topographic sheets and the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, United States-West Coast: Port Hueneme to Santa Barbara, California, Nautical Chart.

2.2 Automatic Data Processing

Digital tape data for OCS Run k-1 (Figure 2) was processed and reformatted on the University of California, Santa Barbara (UCSB) IBM 360/75 system using the standard LARSYS data tape format.[3] Because LARSYS uses one byte per data sample (pixel) and OCS is designed to provide a two byte per data sample format, it was necessary to modify the OCS format. This was accomplished by using the least significant byte for each pixel. As a result, major changes in grey value, (e.g. bright returns from land surfaces) were evidenced by a reset to darker values. Basically, the procedure employed retained the full range of the more subtle grey value (DN) variations; and, in addition expedited data reformatting.

No noise removal preprocessing was attempted because of the non-availability of preprocessing programs. These are currently being implemented at UCSB and noise removal will be attempted on these OCS data sets in the near future.

Computer output products included:

- individual grey maps (shade prints) of flight line k-1 (see Figure 2) for OCS Channels 2, 4, 5, and 7;
- a clustered grey map for OCS Channels 2, 4, 5, and 7 of the same overflight area;
- clustered grey maps from OCS Channels 2, 5, and 7 for three sub-areas along flight line k-1;
- annotated tables showing pairwise separability.

---

[3] LARSYS is an acronym for the multispectral pattern recognition programs developed by the Laboratory for Applications of Remote Sensing (LARS) of Purdue University, Lafayette, Indiana. Version 3.0 has been implemented by the Geography Department of UCSB.

3.0 TARGETS

Four major categories of targets were used to evaluate the detection and interpretability performance characteristics of selected OCS channels. Targets of interest were surface slicks (oil and wind), kelp beds, sediment patterns, and man-made features (fixed structures and merchant vessels). These general classes provided a good sample of the range of target types which the OCS satellite system will encounter. Descriptive information on the distribution/occurrence of individual target types in the Santa Barbara Channel and the potential utility of OCS acquired data for identification and mapping is presented below.

3.1 Surface Slicks (Oil and Wind)

Oil and wind slicks regularly occur over much of the Santa Barbara Channel. These present excellent targets for assessing OCS capability to provide data for discrimination of surface oil pollution and sea state conditions.

3.1.1 Oil Slicks

Most surface oil slicks in the Santa Barbara Channel are produced by natural oil and gas seepage emanating from the sea floor, although occasional production and transportation-related spills also occur. Chronic natural seeps are typically concentrated within four to five miles of the coastal mainland, along active and inactive fault zones. During the October 29, 1975 overflight, several major seeps were known to be active along the Run k-1 flight track (see Figure 2). The most active of these were found west of Goleta and off Summerland and Carpinteria with

lesser seeps surfacing off Capitan, Goleta, and Santa Barbara.

The actual surface configuration of individual slicks in the Channel is quite variable depending on factors such as physical location, volume of oil released (bbl/day), and prevailing climatological and oceanographic conditions. The primary natural forces influencing the behavior of seep-related oil slicks are thought to be surface winds and ocean currents. When winds and currents are strong (i.e., exceeding fifteen knots/hour and approximately 1½ feet/second, respectively) and swell heights build up, little oil remains on the surface due to mixing and evaporation of volatiles. If winds and currents are moderate (i.e., between three and fifteen knots and approximately one foot/per second, respectively), surfacing seep oil moves down wind/down current to form elongated, relatively narrow slicks (Mikolaj, Allen, and Schlueter, 1972). Allen and Schlueter (1969) report observing thin continuous slicks up to five miles in length off Coal Oil Point under such conditions. The authors have observed similar patterns during natural seep monitoring projects conducted for California State Lands Division (Kraus and Estes, 1976) and radar tests sponsored by the U.S. Coast Guard (Estes and Kraus, 1976; Kraus et al., 1977). Conversely, when weather and surface conditions are calm (i.e. winds less than three knots/hour and currents of approximately one foot/second or less), interfacial forces prevent oil from mixing in the water column and heavy surface concentrations of fresh seep oil combine with thick, ropy streamers of emulsified oil. Surface slicks up to 20 square miles in area are not uncommon in the Channel following several days of calm weather.

Earlier studies of oil pollution in the Santa Barbara Channel using multispectral scanner imagery have shown that slicks are most apparent (have the best contrast with water background) in the ultraviolet region and that contrast (detectability) decreases as wavelength increases within the visible spectrum (Stewart et al., 1970; Horvath, 1971). Furthermore, sunglitter patterns on the sea surface tend to accentuate oil/open water reflectance differences, highlighting the former. One objective of this analysis was to determine if these earlier findings were valid for OCS multispectral imagery.

3.1.2 Wind Slicks

Wind slicks are not limited to fixed areas in the Santa Barbara Channel and tend to form more extensive surface patterns than oil. They are especially evident during the afternoon hours when surface and near surface winds are most active. Wind slicks may vary from localized occurrences several hundred feet in length to large area slicks cutting swaths up to twenty miles long and two miles wide. The latter have been observed frequently on Landsat imagery of the Channel and are most pronounced during the late summer and early fall when strong downcanyon winds characteristically blow offshore. Wind slicks, like oil slicks, are best observed in areas surrounding the sunglitter pattern on photography imaged on the visible spectrum (McClain and Strong, 1969; Soules, 1970).

Of interest is the potential use of scanner imagery to determine sea state conditions based on sunglitter patterns created by near-surface wind fields. Cox and Munk (1954), Duntley and Edgerton (1966), and others have shown that the following relationship exists between these glitter patterns and sea state:

- reflectance at the specular point decreases with increasing sea state, and
- width of the diffuse reflection region and the specular point increases with increasing sea state.

This technique of deducing surface wind fields from glitter data would be especially useful over large oceanic areas where conventional data collection is sparse.

In addition to determining the utility of OCS for detecting wind slicks, a secondary objective of our analysis was to attempt to successfully differentiate between wind and oil slicks in those areas where both types were documented on the imagery.

3.2 Kelp Beds

One of the principal benthic marine plant communities of west coast North America is that dominated by the giant bladder kelp, *Macrocystis pyrifera*. As a natural part of the ocean environment, kelp beds provide both food and shelter to numerous marine animals and are a commercially important source of chemical substrates used in a variety of industrial applications and products. Commercially exploitable kelp beds extend along the California coast from Monterey to San Diego and approximately 400 miles south in to Mexican waters off Baja California. The Santa Barbara Channel supports extensive concentrations of giant kelp both along the mainland coast from Point Conception to Ventura and surrounding Anacapa, Santa Cruz, Santa Rosa, and San Miguel islands (see Figure 2).

Kelp grows best in nearshore areas where strong currents insure a continuous supply of the nutrients necessary to sustain the giant plant. The lower limit of growth off the California coast is approximately 30 meters,

the depth at which life giving sunlight begins to rapidly decrease. When sea conditions are relatively calm and swell heights are less than three to four feet, floating kelp provides an excellent reflectance target and is readily imaged in the visible spectrum. When swells exceed four feet, kelp is often submerged and not visible on conventional imagery.

The California Department of Fish and Game and several university and private industry research organizations are currently exploring the use of satellite imagery for inventorying and mapping kelp bed biomass along the California coast (Rhoades, G.J., 1977). Most of the ongoing work involves Landsat digital and photographic imagery with promising results achieved by several researchers. Ocean Color Scanner on NIMBUS G represents a potential source of sequential satellite imagery for these projects.

3.3 Sediment Movement

Coastal engineers and planners have long been interested in sediment movement as a means to measure and predict changing coastal processes. Currently, the U.S. Army Corps of Engineers and the California Department of Navigation and Ocean Development are involved in a cooperative program to study and document shoreline erosion along coastal California. This research program, one of a number of similar projects underway in the United States, is intended to identify broad erosion problems and sources of coastal sediment using remote sensing and standard botton survey methods. Sediment movement is not yet understood with the precision of other hydraulic phenomena and the importance of sequential imagery of shorelines has been understated as a tool for defining hydraulic processes along sandy coastlines (Pirie and Murphy, 1975). The use of satellite photography, offering

a synoptic view, is presently being explored by several agencies as a possible tool for mapping sediment transport.

Sand movement along shorelines occurs within relatively distinct sections of the coastal zone known as littoral cells. These extend from the point where a sand supply is introduced to the shoreline, downdrift to a resting point or the mouth of a submarine canyon where the sand is temporarily deposited or irretrievably swept out to sea. Several major littoral cells have been documented in the Santa Barbara Channel OCS test area. The most prominent of these are located off Santa Barbara Harbor and Breakwater, off Ventura and southest of Ventura. Our basic interest in analyzing OCS imagery for sediment movement patterns was to identify the sensor channels (wavelength bands) showing the greatest promise for this application. No effort was made to measure littoral cell areal extent or to estimate sand volumes based on OCS imagery.

3.4 Man-Made Targets

3.4.1 Fixed Targets

Fixed structures in the Santa Barbara Channel provided a number of known targets whose image responses could be accurately measured. A total of seven piers, three harbor breakwaters, and ten oil production platforms were used as representative targets. Table 2 provides data for each target, including location, base dimensions, and type composition.

TABLE 2 Representative Man-Made Targets (Fixed Location) in the Santa Barbara Channel Test Area.

Target	Location	Dimensions (≃)	Comp.*	Remarks
		PIERS		
Biltmore	SE of Santa Barbara	500' x 30' x 20'	W	
Casitas	SE of Carpinteria	750' x 40' x 25'	C&W	Causeway 600' x 20'; finger 150' x 40'
Ellwood	S of Ellwood	2000' x 160' x 25'	W	Causeway 1900' x 15'; finger 100' x 160'
Goleta	S of Goleta	1000' x 30' x 20'	W	Causeway 950' x 18'; finger 50' x 30'
Hueneme	SE of Port Hueneme	850' x 200' x 20'	W	Causeway 800' x 15'; finger 50' x 200'
Stearns	Santa Barbara	1445' x 76' x 16'	W	Causeway 1195' x 36'; finger 250' x 76'
Ventura	Ventura	1700' x 40' x 20'	W	
		BREAKWATERS		
Channel Is. Harbor	SE of Ventura	2300' x 15' x 10'	R	
Santa Barbara	Santa Barbara	2000' x 15' x 10'	R	
Ventura Marina	S of Ventura	1500' x 15' x 10'	R	
		OIL PRODUCTION PLATFORMS		
Platform A	Off Summerland	112' x 134' x 99'**	S	
Platform B	Off Summerland	112' x 134' x 99'	S	
Platform Hazel	Off Summerland	110' x 110' x 95'	S	
Platform Heidi	Off Carpinteria	110' x 110' x 95'	S	
Platform Hilda	Off Summerland	110' x 110' x 95'	S	
Platform Hillhouse	Off Summerland	110' x 135' x 99'	S	

TABLE 2 (continued)

Target	Location	Dimensions (≃)	Comp.*	Remarks
Platform Hogan	Off Carpinteria	121' x 125' x 99'	S	
Platform Holly	Off Coal Oil Point	80' x 125' x 84'	S	
Platform Hope	Off Carpinteria	110' x 110' x 95'	S	
Platform Houchin	Off Carpinteria	123' x 125' x 89'	S	

---

*C=Concrete; R=Rock; S=Steel; W=Wooden

**All oil platform heights are measured from MLLW to the top of the helipad.

3.4.2 Vessels

Six large vessels were identified on the 1:120,000 scale CIR sea truth imagery for Run i-j; no vessels were detected on the imagery for Run k-l (see Figure 2). Five of the vessels identified on the sea truth imagery were underway in mid-Channel. A sixth vessel was situated off the Channel Islands Marina Breakwater, southest of Ventura. It could not be determined whether this vessel was anchored or underway.

Estimates of the size and type vessels underway in the Channel follows:[4]

Type	Location	Estimated Length	Remarks
1. Oil Tanker	Off NW end of Santa Cruz Island	700'	Westbound
2. Car Barge	Off NW end of Santa Cruz Island	300'	Westbound just north of oil tanker
3. Oil Tanker	Off NE end of Santa Rosa Island	650-700'	Eastbound
4. Freighter	Off NW end of Santa Cruz Island	500-550'	Eastbound
5. Containership	N of midpoint of Santa Cruz Island	600-650'	Eastbound

The vessel located off Channel Islands Marina was probably a missile tracking vessel or U.S. Navy transport homeported at Port Hueneme. Vessel length is estimated at 550-600'.

---

4 Tentative identification was based on review of the Los Angeles Harbor Vessel arrivals and departures for October 29, 1975 (Los Angeles Times, "Ship Movements").

Because of insufficient sea truth documentation of surface slicks, kelp bed distribution, and sediment movement in the Santa Barbara Channel on October 29, 1975, our analysis of the OCS photographic data was primarily qualitative in nature. However, an attempt was made to rate target detection performance and target interpretability by sensor channel and class of target based on qualitative criterion. Quantitative evaluations of the digital tape data were similarly affected by incomplete sea truth information, as well as noise in the system.

4.1 ANALYSIS OF PHOTOGRAPHIC IMAGERY

4.1.1 Target Detection/Target Interpretability

Tables 3 and 4 provide summary information on the target detection performance of OCS using black-and-white and color combined photographic imagery acquired on Runs i-j and k-l (see Figure 2). Table 5 indicates general target interpretability performance for each run. The tables include data for OCS Channels 2, 4, 5, and 7 and the optically combined imagery (OCS Channels 2, 5, and 7).

4.1.1.1 Surface Slicks

No oil slicks were located on the OCS scanner or CIR sea truth imagery, although oil is normally visible on the ocean surface at several locations off the Santa Barbara coast. It is possible that oceanographic and climatological conditions on the overflight date combined to disperse and submerge seep oil, thus preventing formation of visible surface slicks. This could not be confirmed due to the absence of low-level sea truth imagery for the test area, and the non-availability of accurate wave height/surface swell data for the Channel on October 29. However, wind slicks were clearly imaged on sea truth and scanner imagery for both runs. In all cases, wind slicks were imaged as dark surface patterns against a lighter toned surface in areas of sunglitter.

Channels 4 (0.544 um) and 7 (0.662 um) and the color combined imagery proved the most reliable for wind slick detection. In each case, all known slicks along Runs i-j and k-l were detected and target interpretability was rated "good." Contrast between wind slicks and the background sea surface on Channel 5 (0.582 um) was variable, although all wind slicks in the test

TABLE 3 Detection/Non-Detection of Known Targets Using OCS B&W and Color Combined Photographic Imagery - Ventura and Channel Islands Harbor - very faint.

Category	Comments on Target Detection/Non-Detection
Target Detection - <u>Surface Slicks (oil and wind)</u>	No known natural oil seeps in target area. Wind slicks regularly observed in mid Channel and off Channel Islands Harbor/Ventura (evident on 1:120,000 CIR sea truth imagery).
Channel 2	Wind slick detected off Ventura to Santa Rosa Islands - October 29, 1975.
Channel 4	" " " " " " - well defined.
Channel 5	" " " " " " - very faint.
Channel 7	" " " " " " - well defined.
Color Combined	" " " " " " - very faint.
Target Detection - <u>Kelp</u>	No kelp targets in imaged area except near northwestern tip of Anacapa Island (masked by blooming and scanner blind spot).
Target Detection - <u>Sedimentation Movement</u>	Regularly observed offshore from Ventura southeastward.
Channel 2	No discernable pattern.
Channel 4	Well defined pattern; especially off Ventura and southeast toward Channel Islands Harbor.
Channel 5	Sediment patterns observed; not well defined.
Channel 7	" " " "
Color Combined	Well defined pattern; especially off Ventura and southeast toward Channel Islands Harbor

TABLE 3 (continued)

Category	Comments on Target Detection/Non-Detection
Target Detection - Man-Made Targets (Oil Platforms and Piers)	Seven oil production platforms (off Carpinteria), two piers (Ventura Pier - 1700' x 40'; Hueneme Pier - 850' x 15'), and two concrete breakwaters (Ventura Marina - 1500' x 15'; Channel Islands Harbor - 2300' x 15') located in imaged area.
Channel 2	No platforms, piers, or breakwaters detected.
Channel 4	Four of seven platforms detected; no piers; Ventura Marina breakwater detected.
Channel 5	No platforms, piers, or breakwaters detected.
Channel 7	All seven platforms visible; no piers detected; both breakwaters detected.
Color Combined	" " " " "; Ventura Marina breakwater detected.
Target Detection - Man-Made Targets (Merchant Vessels)	Six large merchant/naval vessels identified (five underway in mid-Channel off Anacapa and Santa Cruz Islands; one anchored off Port Hueneme). While not positively identified as to type, the mid-Channel vessels are thought to include two oil tankers and three cargo vessels; vessel off Port Hueneme probably a Navy transport.
Channel 2	No vessels detected.
Channel 4	All six vessels detected.
Channel 5	" " " "; faint returns.
Channel 7	" " " "; sharp returns (ship wakes visible).
Color Combined	" " " " " " (" " ").

TABLE 4 Detection/Non-Detection of Known Targets Using OCS B&W and Color Combined Photographic Imagery - Carpinteria to Capitan - October 29, 1975.

Category	Comments on Target Detection/Non-Detection
Target Detection - Surface Slicks (oil and wind)	Four major natural seep areas documented along flight line (offshore of Carpinteria/Summerland; between Platforms A & B off Summerland; off Santa Barbara between Goleta Point and Capitan; numerous wind slicks in mid-Channel.
Channel 2	No distinct oil slick patterns observed; faint returns from wind slicks SE of Goleta.
Channel 4	No oil seeps detected in nearshore area; distinct wind slick patterns in lower third of image SE of Capitan, SE of Goleta, and SE of Carpinteria.
Channel 5	No oil seeps detected; fairly good discimination of wind slick patterns off Goleta and Carpinteria; slick SE of Capitan not detected.
Channel 7	No oil seeps detected; good returns from wind slicks off Capitan, Goleta, and Carpinteria.
Color Combined	" " " " " " "
Target Detection - Kelp	Thirteen known kelp beds between Carpinteria-Capitan. High waves on overflight day may have partially submerged kelp and masked returns.
Channel 2	No kelp detected - returns from water fairly homogenous over imaged area with no major differences in tone/contrast.
Channel 4	No kelp detected.
Channel 5	Kelp detected off Carpinteria, Santa Barbara, and Goleta; several minor beds not detected.
Channel 7	No kelp detected.
Color Combined	All major kelp beds imaged; good contrast between light red/orange mottled returns from kelp and green/blue from ocean.

TABLE 4 (continued)

Category	Comments on Target Detection/Non-Detection
Target Detection - Sediment Movement	Sediment patterns observed off Carpinteria, Santa Barbara, and Goleta on October 29, 1975.
Channel 2	No sediment patterns detected; ocean returns fairly homogenous.
Channel 4	Apparent sediment patterns off Carpinteria, Santa Barbara, and Goleta.
Channel 5	" " " " "
Channel 7	" " " " "
Color Combined	Sediment patterns very poorly defined.
Target Detection - Man-Made Targets (oil platforms and piers)	Ten oil platforms (nine off Carpinteria/Summerland and one SW of Goleta) and five piers (Ellwood, Goleta, Santa Barbara (2), and Carpinteria).
Channel 2	None detected.
Channel 4	Two platforms detected off Summerland and five of seven detected off Carpinteria; Platform SW off Goleta not detected; no piers detected.
Channel 5	Two platforms detected off Summerland; other eight platforms not detected; no piers detected.
Channel 7	Nine platforms off Carpinteria and Summerland detected; platform SW of Goleta not detected; 1900' Ellwood pier detected; no others.
Color Combined	Nine platforms off Carpinteria and Summerland detected (returns vary significantly in sharpness); other platform and piers not detected.
Target Detection - Man-Made Targets (Merchant Vessels)	No large merchant vessels observed in the imaged area.

:

TABLE 5 Target Interpretability Using OCS B & W and Color Combined Photographic Imagery

Run i - j: Ventura to Santa Rosa Island (October 29, 1975)

Target	Channel 2	4	5	7	CC*
Surface Slicks**	P***	G	F	P	F
Kelp	ND	ND	ND	ND	ND
Sediment Movement	ND	G	P	P	F/G
Man-Made:					
Piers/Oil Platforms	ND	F	ND	G	F
Merchant	P	F	P	G	G

Run k - l: Carpinteria to Capitan (October 29, 1975)

Target	Channel 2	4	5	7	CC*
Surface Slicks**	P***	G	F	G	G
Kelp	ND	ND	P	ND	G
Sediment Movement	ND	F	P	P	F
Man-Made:					
Piers/Oil Platforms	ND	P	P	F	P/F
Merchant Vessels	NP	NP	NP	NP	NP

* Color Combined - Channels 2, 5, and 7.

** Wind only (no oil); visible only in area adjacent to sun glint (i.e., bottom one-third of image).

*** Target Interpretability Key:

- Good - Target sharp and well-defined. Where targets were clustered, individual targets were clearly discernable.
- Fair - Target readily identifiable, but lacked sharpness and clarity. Individual targets often merged together or with image background.
- Poor - Target identifiable only through prior knowledge of exact location. Return lacked sharpness and characteristically merged with background.
- ND - Target not detected.
- NP - No target present in imaged area.

area were imaged. Target interpretability was rated "fair." Channel 2 (0.465 um) was the least effective band for slick detection. Several wind slick targets merged with a homogenous sea surface background at this wavelength and were not detected. A target interpretability rating of "poor" was assigned to this channel. Figure 3 illustrates the detection performance characteristics of the four individual and three color combined channels against known slicks along Run k-1.

Because of the absence of known oil slick targets in the test area, it was not possible to assess the relative ability of individual scanner channels to differentiate between oil and wind slicks. This will be attempted in our next report using density slicing and microdensitometer readings from OCS imagery acquired June 23, 1976 over the Santa Barbara Channel. Reliable sea truth data are available for that date.

4.1.1.2 Kelp

Thirteen major kelp beds provided potential targets for the Ocean Color Scanner. These were located along the Santa Barbara coast from Carpinteria on the east to Capitan on the west (Figure 2). Because sensors imaging in the visible portion of the electromagnetic spectrum may be limited to detecting near surface or surface phenomena only, it was necessary to verify the presence of floating kelp in the test area prior to analyzing the scanner imagery.[5] Examination of the coincident 1:120,000 scale CIR sea truth photography provided by NASA showed evidence of surface kelp in all

---

[5] Kelp is often submerged slightly below the surface and virtually non-detectable by remote sensing systems when surface swells exceed several feet in height.

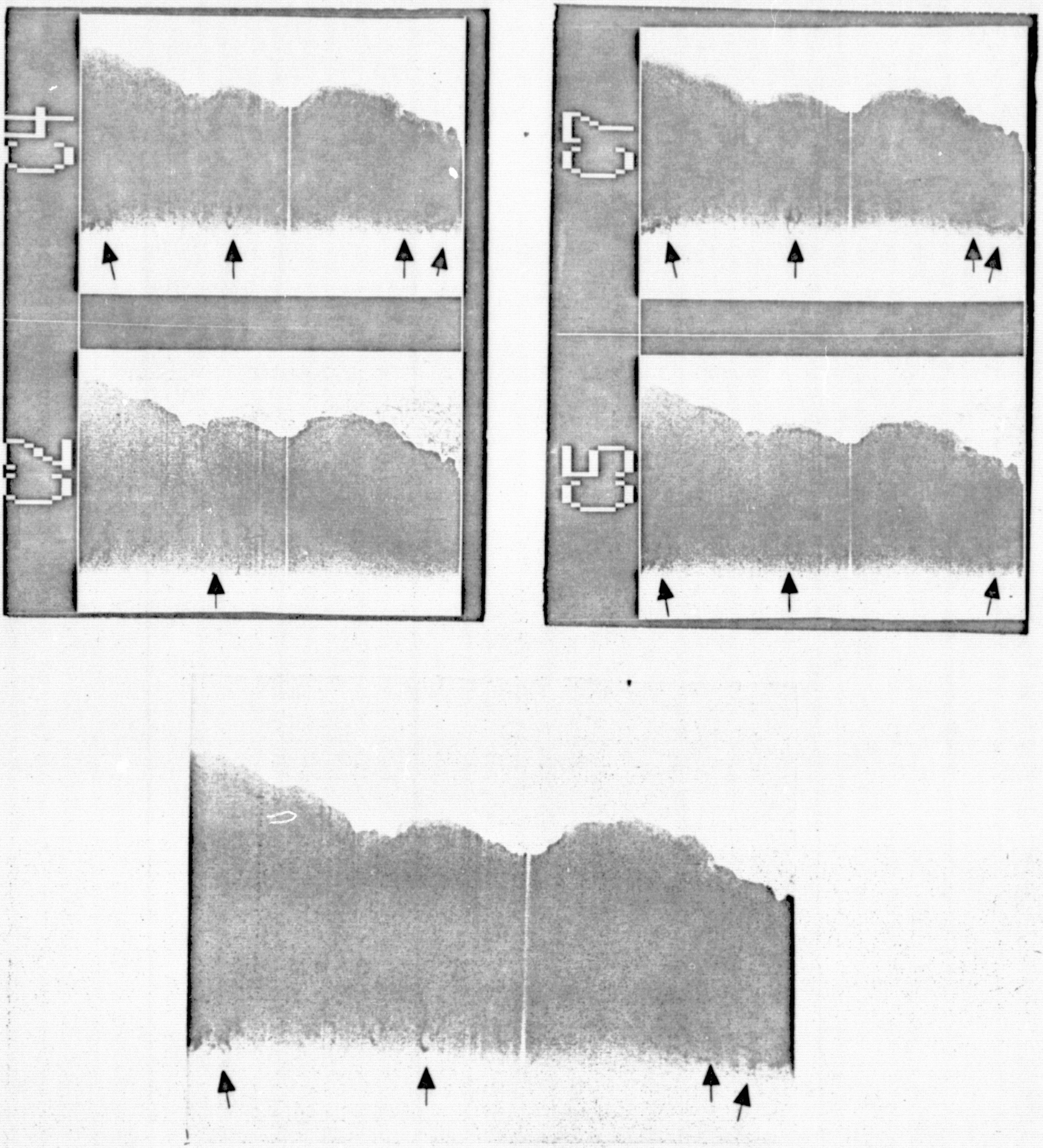


Figure 3. Wind Slick Detection (OCS Channels 2, 4, 5, and 7; Color Combined Image - Channels 2, 5, and 7). Santa Barbara Channel, October 29, 1975. OCS flightline k-1. All known slicks were recorded on Channels 4 and 7 and the color combined imagery.

beds, although the total areal extent of several beds appeared smaller than normally would be expected. This may have been due to partial submergence of kelp by surface swells or reduced bed size due to cyclic later summer/early fall die-off.[6] Known kelp beds west of Ventura and around the off-shore islands could not be located on sea truth imagery for Run i-j (Figure 2), thus no analysis was made of OCS kelp detection performed for that run.

The color imagery combining Channels 2 (0.465 um), 5 (0.582 um), and 7 (0.662 um) proved the most reliable for detecting kelp. Identification of kelp beds was often enhanced by excellent contrast between floating kelp, which appeared reddish brown, and the light to dark green ocean surface. Noticeable degradation in kelp/water contrast was noted west of Goleta, however. This may have been the result of image blooming at the land/water interface or noise in the system. Overall target interpretability was ranked "good " Channel 5 (0.582 um) was the only individual band where kelp was successfully imaged. Faint responses were recorded on that Channel for floating kelp off Carpinteria, Santa Barbara, and Goleta. However, several major beds were not detected. Target interpretability for Channel 5 was rated "poor." No kelp was discriminated on Channels 2 (0.465 um), 4 (0.544 um) or 7 (0.662 um). Figure 4 compares kelp detection performance for the four individual channels and color combined channels using imagery acquired on Run k-l.

---

[6] Extensive deterioration of healthy kelp beds has been documented in late summer and early fall off the southern California coast by marine biologists (North, 1957; Dawson et al., 1960). Most researchers cite increased surface temperatures as the major factor leading to the death or die-back of individual plants through changes in metabolic rates and the soluability of metabolic gases.

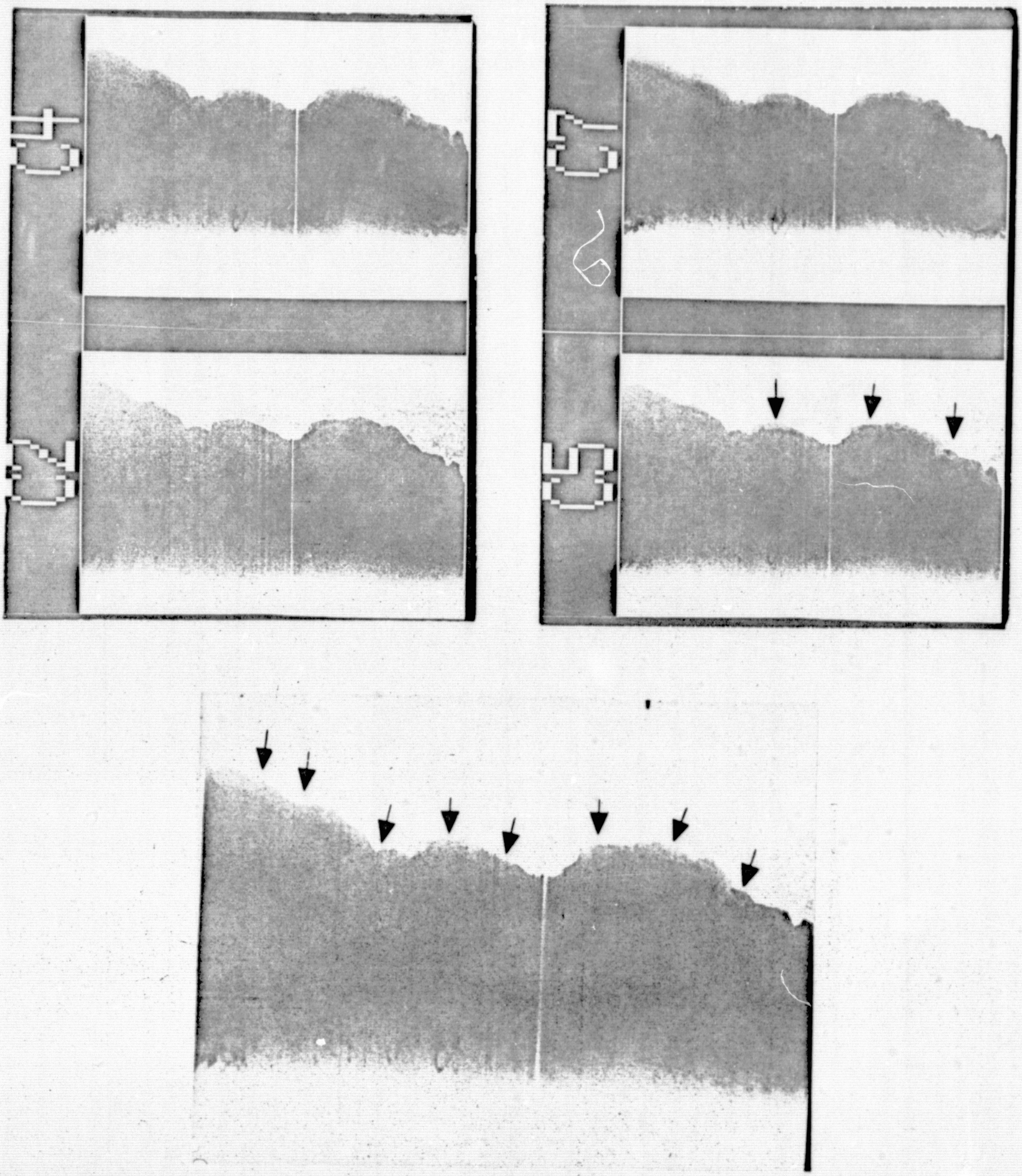


Figure 4. Detection of Kelp (OCS Channels 2, 4, 5, and 7; Color Combined Image - Channels 2, 5, and 7). Santa Barbara Channel, October 29, 1975. OCS flightline k-1. The color combined channel provided maximum detection response.

Since the objective of this initial evaluation was to determine the ability of individual OCS channels to image kelp, and not to assess the utility of the scanner data as a source of kelp biomass data, no effort was made to derive estimates of the areal extent of individual beds. This may be attempted in our next report using imagery acquired June 23, 1976.

4.1.1.3 Sediment Movement

Gross water surface patterns tentatively identified as sediment-related were located on sea truth imagery for Runs i-j and k-l. These comprised a longshore pattern originating near the mouth of the Ventura River (west of Ventura), a large littoral cell extending offshore from the Santa Clara River mouth (east of Ventura), and several smaller cells located off Goleta, Santa Barbara Harbor, and Carpinteria. Sediment patterns of the Ventura and Santa Clara rivers provided the best targets for analysis. Both cells extended several miles offshore, driven by currents and wind.

Channel 4 (0.544 um) and the color combined imagery incorporating Channels 2 (0.465 um), 5 (0.582 um) and 7 (0.662 um) provided the best sediment to water contrast. On both sets of imagery, sediment patterns were clearly defined as mottled, light toned plumes against a darker, more homogenous sea surface. Sediment movement off the Ventura River appeared to be affected by an east-west longshore current as well as an offshore current which carried suspended materials toward mid-channel then eastward. Sediment transport east and west of the Santa Clara River was longshore and offshore, with currents appearing to be the major carriers. At the

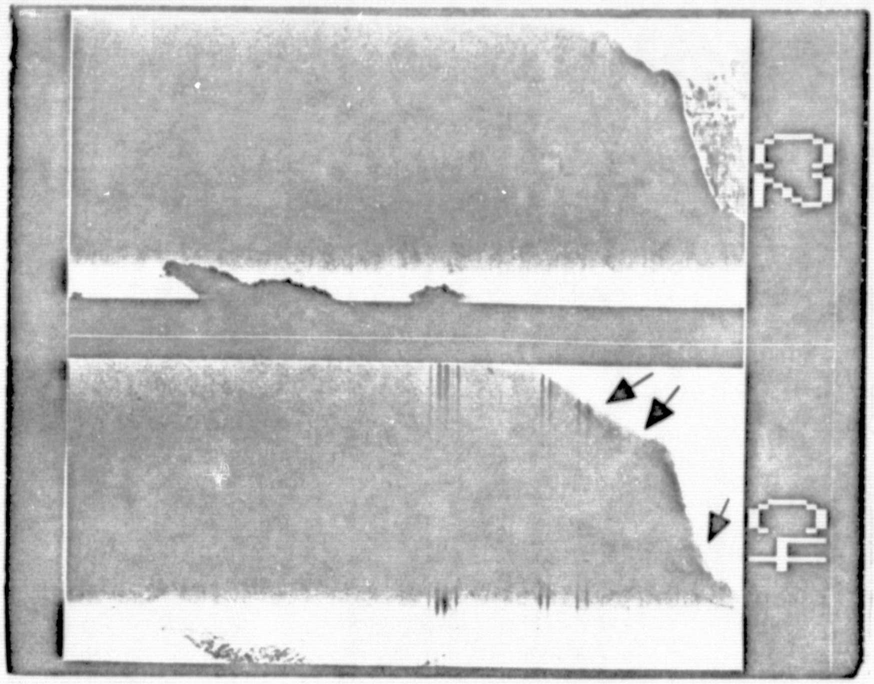
time of image acquisition, no water was flowing to the ocean from the rivers and it was determined that most sediment activity was generated by wave action. Target interpretability using imagery from Channel 4 was rated "good." The color combined imagery was ranked "fair-good." Sediment movement also was detected on Channels 5 and 7. However, the patterns recorded on both bands were considerably smaller in extent than those imaged on Channel 4 and the color combined channels. Apparently, the lighter density sediments near the littoral cell boundaries were not detected on Channels 5 or 7. Target interpretability was rated "poor" for both channels. No visible sediment patterns were detectable on Channel 2. Figure 5 illustrates the performance of Channels 2, 4, 5, and 7 and the color combined (three channel) imagery for detecting sediment movement.

4.1.1.4 Man-Made Targets

4.1.1.4.1 Fixed Targets (Piers/Breakwaters and Oil Platforms)

Target detection performance by the OCS against fixed man-made structures in the nearshore and offshore environments of the Santa Barbara Channel was variable by channel and extremely dependent on target size and location. For example, coastal targets such as piers and breakwaters tended to merge with shoreline returns or present too narrow of a cross section to be detected. Conversely, oil platforms were more visible providing a light toned response against the darker ocean background and a relatively large surface area/target cross section.

Channel 7 (0.662 um) proved best for detecting fixed targets, followed by the color combined channels (2, 5, and 7). Nine of ten oil drilling platforms along Run k-1 were imaged and two of five piers (Ellwood and



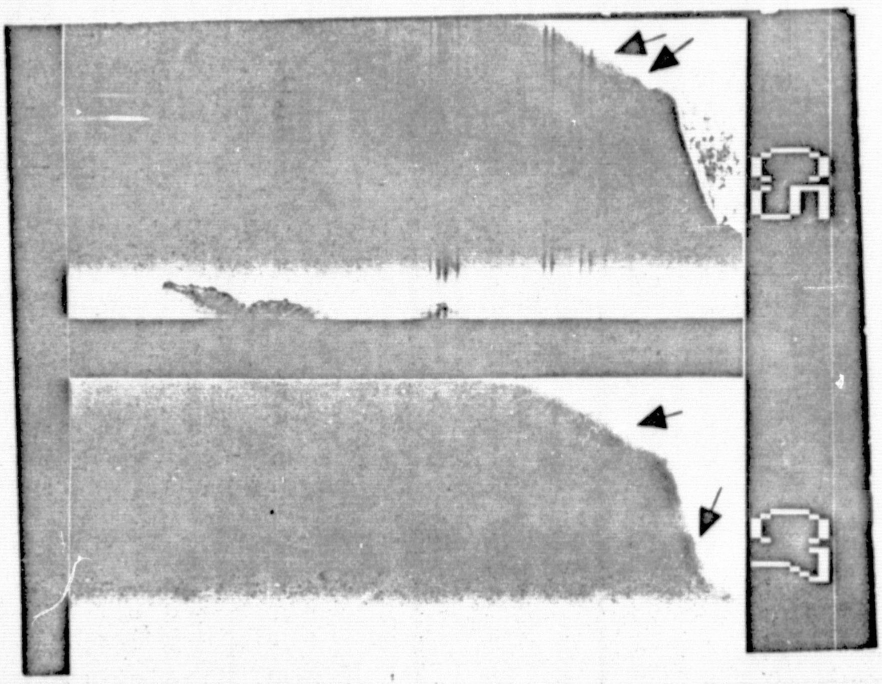
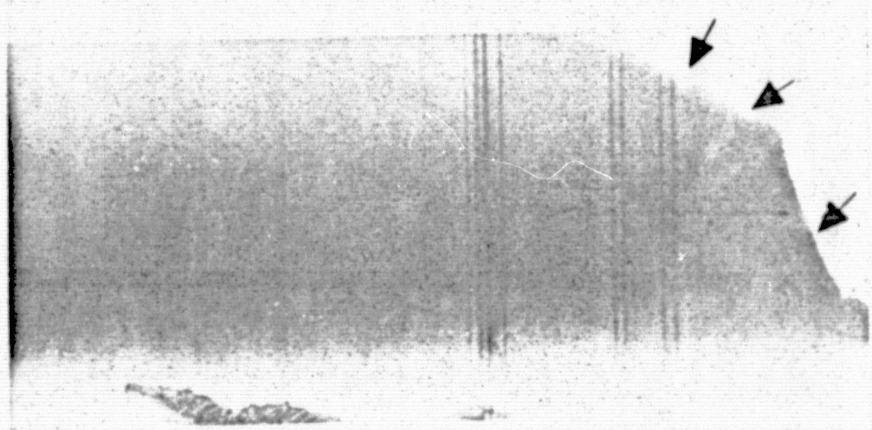


Figure 5. Surface Sediment Patterns in the Santa Barbara Channel (OCS Channels 2, 4, 5, and 7 - Color Combined Image - Channels 2, 5, and 7). OCS filghtline i-j, October 29, 1975. Maximum detection achieved by Channel 4 and color combined imagery.



Stearn's) were postively identified on both. The other piers (Goleta, Biltmore, and Casitas) could not be separated from blooming patterns that extended slightly offshore at many locations along the land/water interface. The blooming was especially pronounced on the color combined imagery. Target interpretability for Channel 7 was rated "fair" against fixed targets; the color combined imagery was rated "poor-fair." Seven of ten oil platforms were recorded by Channel 4 (0.544 um); two of ten on Channel 5 (0.582 um). No piers were imaged on imagery produced by either channel and both were ranked "poor" in terms of target interpretability. No platforms or piers were detected by Channel 2. Figure 6 illustrates target detection and interpretability performance of individual and combined OCS channels against fixed targets in Santa Barbara Channel using imagery acquired during Run k-1.

4.1.1.4.2 Vessels

An evaluation of OCS against moving ship targets was accomplished using imagery acquired on Run i-j. As previously indicated in Section 3.4.2, six large vessels were identified in the test area using the 1:120,000 scale sea truth photography. While positive identification of the ships as to type and size could not be made from sea truth data, targets were tentatively identified as two 650-700' tankers, a 600-650' containership, a 550-600' naval transport, and a 300' car barge. The five commercially operated vessels were underway in mid-Channel off Santa Cruz Island; while the naval transport/tracking vessel was anchored or slowly underway southeast of Ventura (see Figure 2).

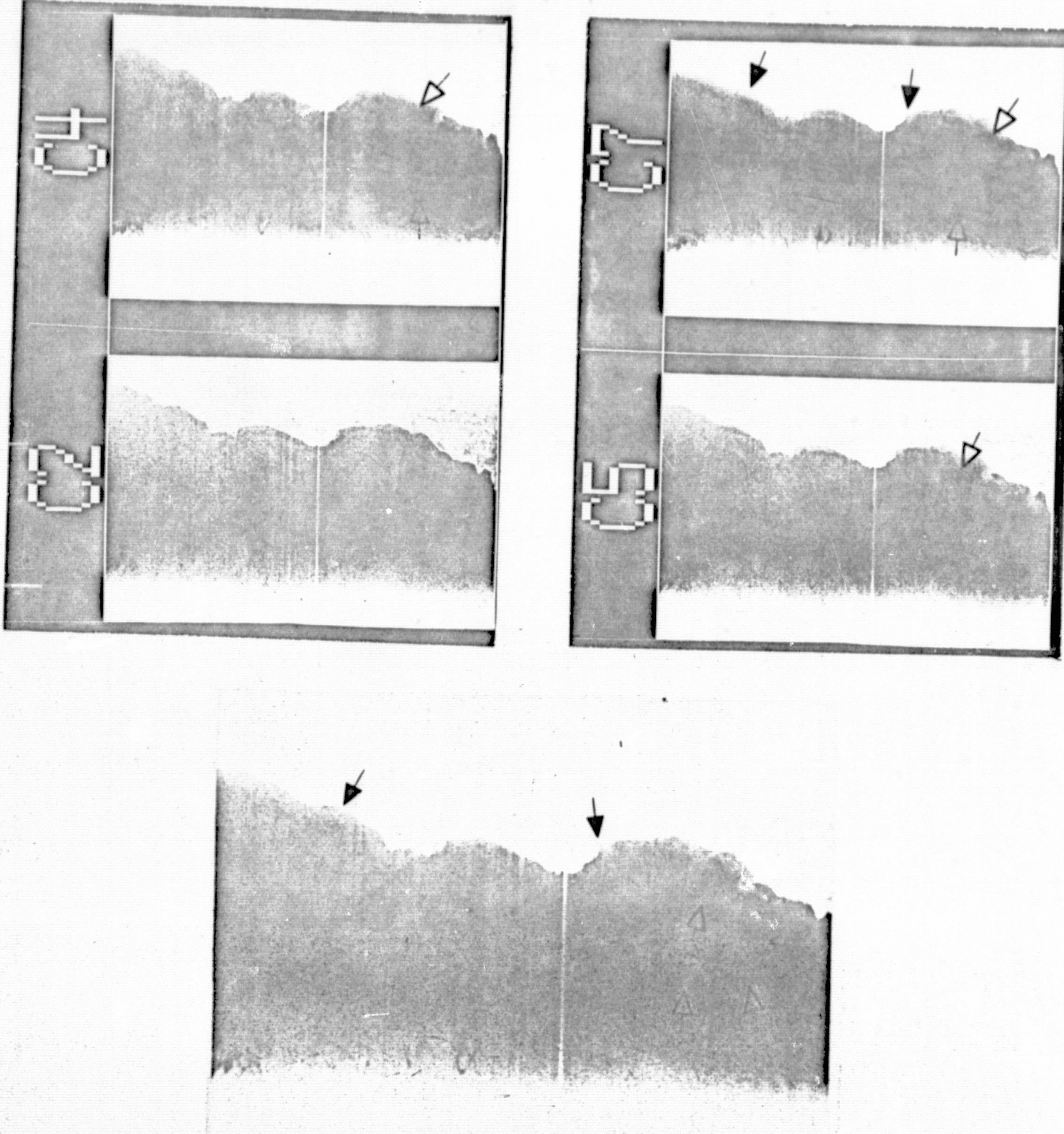
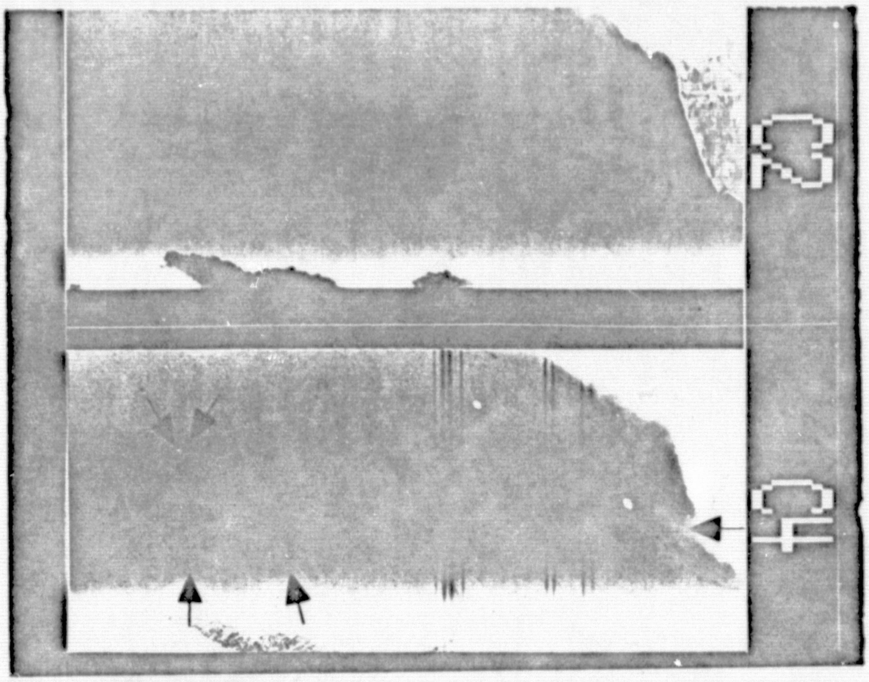


Figure 6. Detection of fixed, man-made targets in the Santa Barbara Channel, October 29, 1975, by OCS Channels 2, 4, 5, and 7 and Color Combined Imagery (Channels 2, 5, and 7). Major targets included oil platforms and piers. Channel 7 proved best for detecting fixed targets, imaging nine of ten offshore oil platforms and two of five piers. (Note: Target detail on above copy photographs is not up to standards of original imagery provided by NASA/GSFC).

Ship targets were visible on scanner imagery from all channels (individual and combined) except Channel 2 (0.465 um). Target interpretability varied by channel, with imagery from Channel 7 (0.622 um) and the combined channels (2, 4, and 7) showing the sharpest returns, followed by Channels 4 (0.544 um) and 5 (0.582 um). These were ranked "good," "good," "fair," and "poor," respectively. Ship wakes were visible on Channel 7 and the color combined imagery. One problem encountered in manual interpretation of the imagery was in clearly differentiating between white ship targets and printing gliches and imperfections in the photographs provided by NASA. While this did not adversely affect our analysis, it could result in interpretation errors where correlative sea truth imagery was not available. Figure 7 shows OCS imagery obtained during Run i-j and permits comparison of ship target detection performance by individual and combined channels.

4.2 Digital Analysis

Analysis of digital data from Channels 2, 4, 5, and 7 was accomplished employing the standard LARSYS classification programs. LARSYS provided equal-area histograms for each channel, which optimized contrast in the grey map preliminary scan. Cluster analysis of selected sub images also was performed using all four channels of digital data. Under a seven or ten cluster criterion, 99% of all pixels were assigned to a cluster by using up to 15 iterations. Table 6 summarizes the relative separability of clusters used for initial training set designation and classification runs. Further classification runs were not attempted due to excessive "noise" within the data set. Figure 8 illustrates this "noise" problem by showing



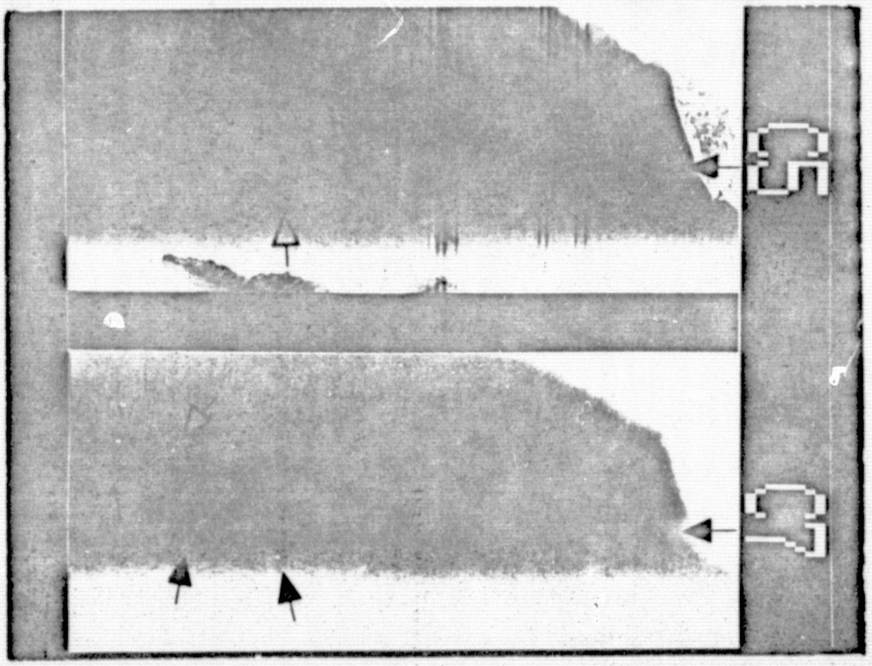
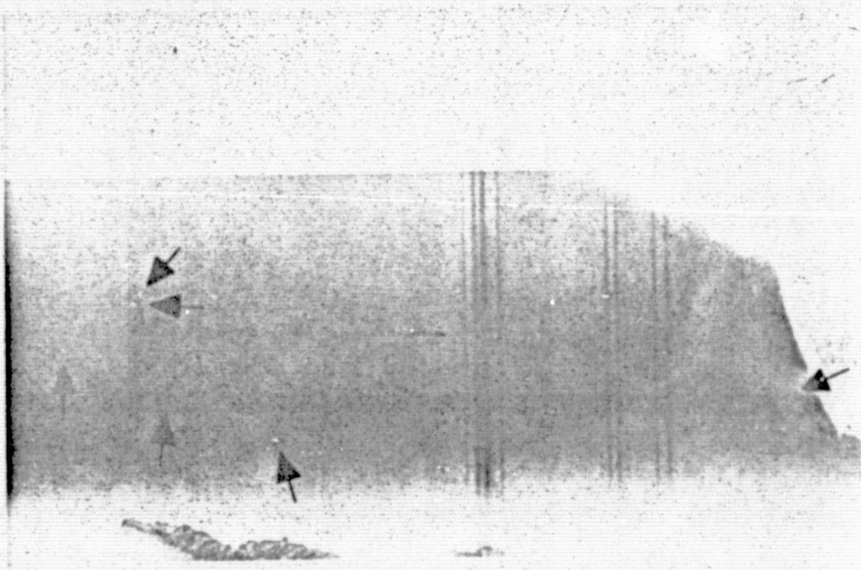


Figure 7. Detection of Ship Targets (OCS Channels 2, 4, 5, and 7; Color Combined Imagery - Channels 2, 5, and 7). Santa Barbara Channel, ~~October~~ October 29, 1975. OCS flightline i-j. Five large merchant vessels in mid-Channel and a Navy transport southeast of Ventura were detected on Channels 4, 5, and 7 and the color combined imagery on the original photographs.



SEPARABILITY INFORMATION

I	J	D(I,J)	D(I)	D(J)	D(I)+D(J)	QUOT
1	2	130.617	49.629	45.527	95.156	2.003
1	3	69.414	34.694	22.080	56.773	1.223
1	4	108.151	30.555	16.760	47.315	2.285
1	5	137.730	30.266	10.958	41.224	3.341
1	6	213.323	29.708	43.189	72.897	2.926
1	7	200.445	21.433	43.492	64.925	3.087
2	3	150.451	30.690	22.382	53.072	2.835
2	4	155.197	23.733	16.466	40.254	3.855
2	5	154.585	20.869	10.165	31.033	4.981
2	6	226.324	21.955	42.969	64.924	3.494
2	7	256.241	18.960	38.683	57.643	4.445
3	4	41.211	19.814	15.946	35.760	1.152
3	5	69.606	20.635	10.426	31.061	2.241
3	6	169.530	19.925	36.462	56.387	3.007
3	7	155.507	17.565	44.723	62.238	2.497
4	5	29.873	16.889	11.224	28.113	1.063
4	6	155.371	14.961	32.143	47.104	3.299
4	7	124.529	17.268	37.695	54.963	2.266
5	6	147.089	8.886	29.331	38.216	3.849
5	7	117.768	8.162	31.524	39.686	2.967
6	7	219.862	29.625	51.150	80.776	2.722

Table 6. The LARSYS cluster separability algorithm is such that a quotient $\geq$ 1.0 indicates good grey value separability. Hence all cluster groups could serve as useful training field data for subsequent classification runs.

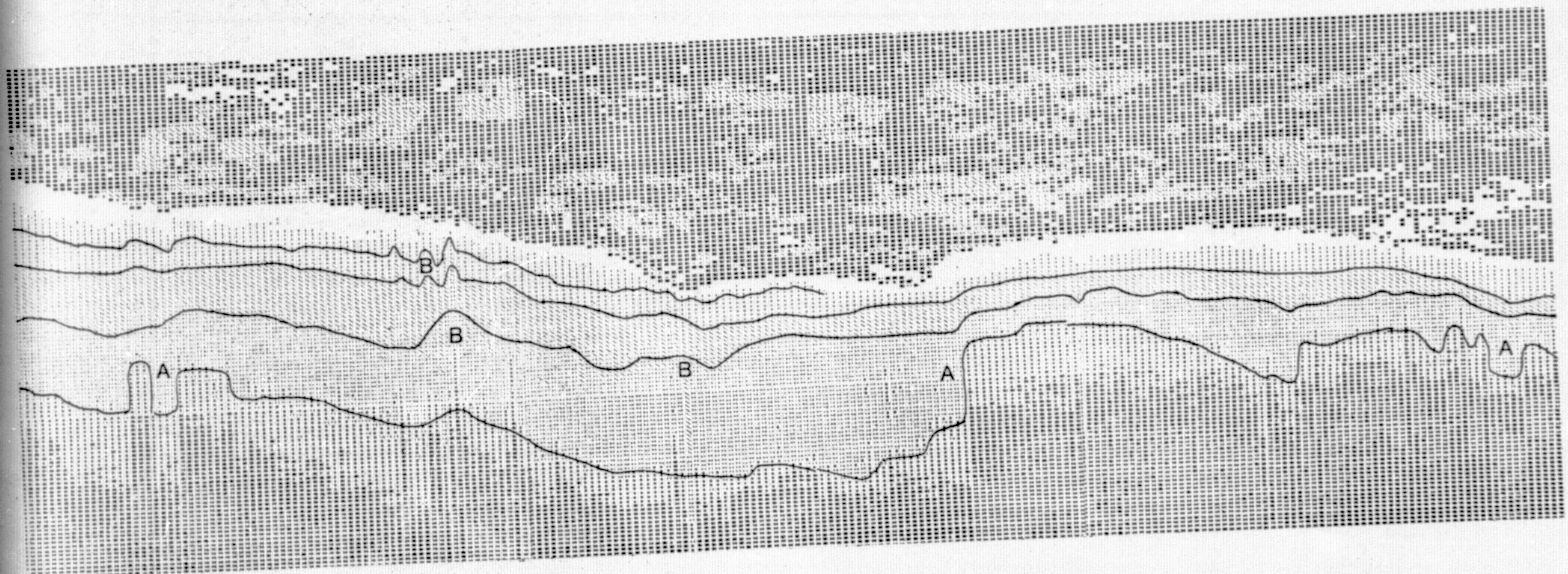


Fig. 8. Grey map showing apparent sensor gain changes at "A" and apparent random signal interference at "B". Both of these effects combine to reduce the overall accuracy of subsequent classification runs.

a portion of the original grey map. Because UCSB's image preprocessing programs are in the process of being implemented, no noise removal corrections were possible.

Clustering was performed on a number of subimages within the Santa Barbara Channel. These included an area of ocean immediately offshore of Santa Barbara/Goleta where kelp beds were located and an area further offshore of Goleta where wind slick patterns were identified on the photographic products. The primary objectives of clustering these subimages were to: 1) reduce the effect of "noise" through signal averaging and, 2) to identify similar picture elements from the four Channels which could be grouped together (in seven and ten class formats) to show distinct signal delineations on the computer output. Figures 9 and 10 illustrate the results of these cluster runs.

The seven class cluster output for areas of kelp indicated a potential for further classification output for certain DN ranges. However, the random signal interference present in the October 29, 1975 data sets prevented further attempts at classification.

Future digital image processing will include noise removal, band ratioing, and selection of training fields for subsequent classification of kelp, oil/wind slick patterns, and near surface sediment plumes. This will be attempted when UCSB's image preprocessing programs are fully implemented.

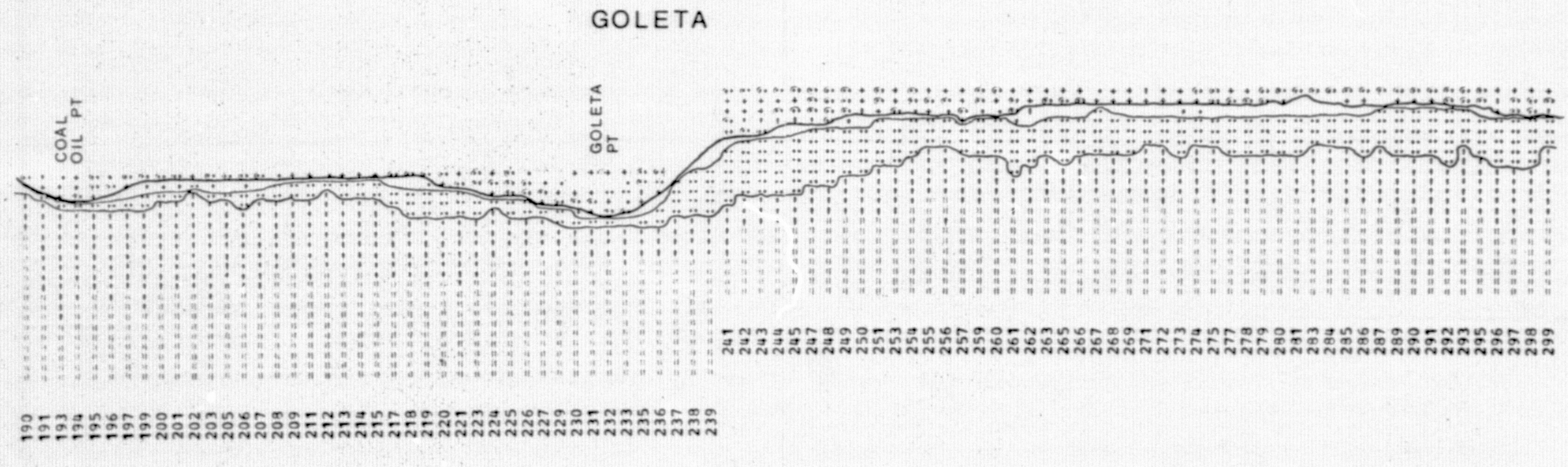


Figure 9. The symbol set outlined appears to coincide with areas of known kelp beds. This cluster run shows that training fields can be identified for future classification runs should the "noise" problem be eliminated.

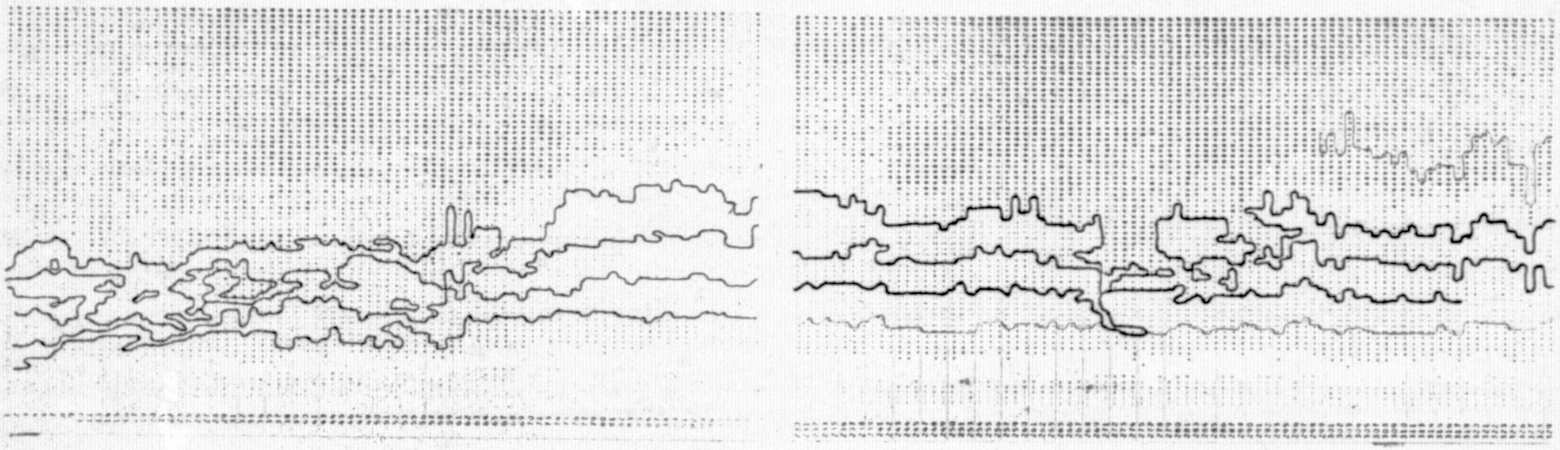


Fig. 10. These printouts of clustered areas of interpreted wind slick patterns show that distinct ranges of grey values exist. However, as a probable result of "noise" and sensor gain changes, the delineations that show up on the above cluster output do not coincide with areas of oil/wind slick patterns interpreted from photographic products.

5.0 SUMMARY CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 Summary Results

Results of our evaluations of photographic imagery and digital tape data from the October 29, 1975 Ocean Color Scanner overflight of the Santa Barbara Channel test site are summarized below. These findings are based on an assessment of the relative target detection and interpretability characteristics for four channels of black-and-white imagery, three channels of color combined imagery, and four channels of digital tape data. Principal targets of interest used in our assessment of OCS performance were surface oil and wind slicks, coastal kelp beds, sediment plumes, and a variety of man-made targets. Photographic imagery were manually interpreted. Digital tape data were processed using standard LARSYS automated analysis techniques.

5.1.1 Photographic Imagery

Color imagery produced by combining OCS Channels 2 (0.465 um), 5 (0.582 um), and 7 (0.662 um) proved the most useful in our analysis in terms of overall target detection and target interpretability performance. The majority of documented individual targets in the test site were recorded on the combined imagery, regardless of target type or location, and image interpretability was rated "fair" to "good" for the four major classes of targets. Target detection and interpretability performance for Channels 4 (0.544 um), 5 (0.582), and 7 (0.662 um) when analyzed individually proved somewhat less consistent than for the combined channels. This held true for most classes of targets. Channel 2 (0.465 um) failed to detect representative targets in three of the four major classes and proved the least reliable of the individual bands (see Tables 3, 4, and 5).

Target detection/target interpretability results for each class of targets were as follows:

- Surface Slicks (Oil and Wind) - No known oil slicks were detected by the individual OCS channels or on the color combined imagery, although surface concentrations of natural seep oil were present on the overflight date. Lack of low-level sea truth prevented positive identification/confirmation of oil slick concentrations. Because of this, it was not possible to make valid judgements concerning the oil detection performance of the OCS system.

  Wind slick patterns were recorded by all four OCS sensor channels and on the combined imagery. Target interpretability was rated "good" for Channels 4 and 7 and the combined channels, "fair" for Channel 5 and "poor" for Channel 2. Wind slicks were visible only in areas of sunglitter, directly below the sensor platform.

- Kelp Beds - Kelp was detected on Channel 4 and the combined channels. All thirteen beds along the Santa Barbara coastline were recorded on the color combined imagery. Interpretability was rated "good." The color contrast between the kelp and open water proved especially helpful in identifying kelp/water boundaries. On Channel 4, only six of thirteen beds could be positively identified. Target interpretability for Band 4 was rated "poor." Tonal contrast between kelp and water was similar, making accurate target identification difficult. No kelp was detected in Bands 2, 5, and 7. In each case, the kelp and water tonal signatures were similar making detection and/or identification impossible.

- Sediment Patterns - Nearshore and offshore sediment patterns in the Santa Barbara Channel were detected on the color combined imagery and all individual OCS bands, except Channel 2. Channel 4 provided the highest sediment/water contrast and target interpretability was rated "good." Color imagery from the combined channels was judged "fair-good;" Channels 5 and 7 both were rated "poor."

  OCS appears to show considerable promise for the mapping and monitoring of sediment patterns and plumes. In particular, determination of areal extent and relative densities may be possible using Channel 4 and the color combined imagery.

- Man-Made Targets - Two subcategories of man-made targets were used in our analysis. These comprised fixed targets (oil platforms and piers) and moving targets (large vessels exceeding 300'). None of the individual or combined channels was particularly reliable against the fixed targets present in the test area. Channel 7 proved most effective, imaging nine of ten oil platforms and two of five piers. However, target interpretability was only ranked "fair" due to faded returns. The color combined channels and Channels 4 and 5 also detected fixed targets with varying results. Image (target)

interpretability for the three was rated "poor-fair," "poor," and "poor," respectively. No fixed targets were detected on Channel 2. The relatively poor performance of OCS against fixed targets may be explained by the types of targets present in the Santa Barbara Channel. For example, oil platforms have a relatively narrow target cross-section, in terms of system resolution limits, which resulted in a faded return or no return in many instances. Piers often merged with the shoreline due to image blooming at the land/water interface and a very narrow target cross-section. The OCS sensor aircraft flew parallel to the coastline with the scanner system imaging perpendicular to the line of flight.

OCS proved more reliable against ship targets than fixed targets. All known large ship targets in the test area were detected on the color combined channels and Channels 4, 5, and 7. Target interpretability was rated "good" for the combined channels and Channel 7. Channels 4 and 5 were rated "fair" and "poor," respectively. One possible explanation for this difference in sensor response to ship and fixed targets is that all ships were moving parallel to the line of flight and provided a long target profile.

5.1.2 Digital Tape Data

Digital analysis for Channels 2, 4, 5, and 7 was accomplished using LARSYS type image processing algorithms. Cluster analysis of selected subimages was performed for all channels. Under a seven or ten cluster criterion, 99% of all pixels were assigned to a cluster. Classification of the digital data, however, was hampered by excessive "noise" in the data set. The seven class cluster output for areas of kelp indicated the potential for further classification over certain DN ranges. No wind slicks, sediment patterns, or man-made targets could be satisfactorily identified on the digital output.

5.2 Recommendations for Future Research

5.2.1 Photographic Imagery

- Assess the relative ability of individual scanner channels to differentiate between oil and wind slicks. This may be attempted in our next progress report using microdensitometer readings and/or through density slicing of OCS imagery acquired June 23, 1976. Adequate low-level sea truth data documenting oil and wind slick locations were obtained for this overflight;

- Evaluate the utility of OCS sensor data for determination of kelp bed biomass and areal extent;
- Assess the capability of OCS data to provide estimates of areal extent and relative thicknesses of sediment patterns.

5.2.2 Digital Tape Data

- Attempt noise removal and band ratioing of OCS digital data using image preprocessing programs now being implemented at UCSB.
- Select training fields for subsequent classification and estimates of oil and wind slick locations and distribution, kelp bed areal extent/biomass, sediment plume area and thickness, and location of fixed targets (using digital data sets for which reliable sea truth data are available).

REFERENCES

Allen, A.A. and R.S. Schlueter. 1969. "Estimates of Surface Pollution Resulting from Submarine Oil Seeps at Platform A and Coal Oil Point." Santa Barbara: General Research Corporation.

Cox, C. and W. Munk. 1954. "Measurement of the Roughness of the Sea Surface from Photographs of Sun's Glitter." Jour. Optical Soc. of America, v. 44, pp. 838-850.

Dawson, E.Y., N. Neuschul, and R.D. Wildman. 1960. "Seaweeds Associated with Kelp Beds Along Southern California and Northwestern Mexico." Pacific Naturalist, v. I, No. 14, March 11, 1960, pp. 30-109.

Duntley, S.Q. and C.F. Edgerton. 1966. "The Use of Meteorological Satellite Photographs for the Measurement of Sea State." Final Report No. II-2, Contract No. NOBS, 86012, U.S. Navy Bureau of Ships Project FAMOS, La Jolla, Ca. 129 p.

Estes, J.E. and S.P. Kraus. 1976. "Airborne Remote Sensing Applications for the Detection and Monitoring of Oil From Natural Seeps and Other Sources. Contract No. LC-6074, California State Lands Division, Long Beach and Governor's Office of Planning Research, Sacramento.

Horvath, R. 1971. "Remote Sensing of Southern California Oil Pollution Experiment." Project No. 714104, Commandment (DAT), U.S. Coast Guard Hq., Washington, D.C.

Kraus, S.P. and J.E. Estes. 1976. "Oil Seep Survey over Coal Oil Point and Santa Barbara Channel, California - October, 1976." Contract No. LC-6083, California State Lands Division, Long Beach.

Kraus, S.P., J.E. Estes, S.G. Atwater, J.R. Jensen and R.R. Vollmers. 1977. "Radar Detection of Surface Oil Slicks." Photogrammetric Engineering, (accepted Sept. 1977).

McClain, E.P. and A.E. Strong, 1969. "On Anomalous Dark Patches in Satellite-viewed Sunglint Areas." Monthly Weather Rev., v.97, pp. 875-884.

Mikolaj, P.G., A.A. Allen, and R.S. Schlueter. 1972. "Investigation of the Nature, Extent and Fate of Natural Oil Seepage off Southern California." Offshore Technology Conference, Houston. Paper No. OTC-1549.

North, W.J. 1957. "Kelp Investigations Program/Progress Report." IMR Reference 57-6, University of California, Institute of Marine Resources; La Jolla, pp. 11-28.

Pirie, D.M. and M.J. Murphy. 1975. "California Coastal Processes Study: Aircraft SRT Project X-098." Final Report. U.S. Army Corps of Engineers, Engineer District, San Francisco (prepared for National Aeronautics and Space Administration, Houston)

Rhoades, G.J. 1977. "Evaluating the Sea Otter-Urchin-Kelp Relationship Using NASA-Landsat Data." IXth International Seaweed Symposium.

Soules, S.D. 1970. "Sunglitter Viewed from Space." Deep Sea Res., v. 17, pp. 191-195.

Stewart, S., R. Spellicy, and F. Polycyn. 1970. "Analysis of Multispectral Data of the Santa Barbara Oil Slick: Final Report 20 September 1969 through 31 March 1970." Report No. 3340-4-F, Infrared and Optics Laboratory, Willow Run Laboratory, Institute of Science and Technology, Univ. of Michigan, Ann Arbor.

Wilkinson, E.R. 1972. "California Offshore Oil and Gas Seeps." California Division of Oil and Gas.